

ELASTOMER COMPOSITIONS FOR USE IN A HYDROCARBON RESISTANT HOSE

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BACKGROUND OF THE INVENTION

The present invention relates generally to polymeric compositions useful in the manufacture of elastomeric components. More particularly, the present invention relates to the field of hoses for use in the automotive industry.

Hoses, particularly rubber hoses are used in a variety of applications in the automotive industry as fuel feed hoses, torque converter hoses, power steering hoses and air conditioner hoses, as well as for industrial and household utility applications such as hydraulic hoses, refrigeration hoses, washing machine hoses, propane gas feed hoses, high pressure air hoses, garden hoses, etc.

It is generally known that rubber surfaces do not always exhibit desired resistance against chemical loads such as organic gases and solvents. Therefore, other approaches for improving the organic gas and solvent resistance of rubber materials included using rubber materials which have a different polarity than the organic gas or solvent, increasing the crosslinking of the rubber material, adding or increasing certain additives, and increasing the wall thickness of the rubber tube material. All of these approaches have a down side. For example, the use of a rubber material having a polarity different from the organic gas or solvent requires the use of expensive rubber materials such as chloroprene rubber, acrylic rubber, epichlorohydrin rubber, and the like; increasing the degree of crosslinking of the rubber used detracts from the softness and flexibility of the rubber; the addition of additives affects the processability and certain physical properties of the rubber; and increasing the wall thickness of the rubber material also increases the weight of the structure. Generally, these undesirable effects overshadow any advantage gained in the improved gas and solvent resistance.

Other approaches employed to improve the impermeability of multilayered rubber hoses include the use of a metal film as a barrier layer coated on one of the inner layers. Such disclosures appear, for example, in U.S. Pat. No. 318,458 to Fletcher where there is disclosed a

multilane tubular structure made from India rubber and having a tin foil liner. Other prior art patents such as U.S. Pat. Nos. 4559,793 to Hanes et al.; 4,759,455 to Campbell et al.; 5,182,147 to Davis; 5,271,977 to Yoshikawa et al.; 5,360,037 to Lindstrom; 5,398,729 to Spurgat; and 5,476,121 to Yoshikawa et al. have attempted similar methods to reduce the permeability of fluids and/or gases through various tubes. Commonly assigned U.S. Pat. No. 6,074,717 to Little et al.; and U.S. Pat. Nos. 4,779,673 and 5,488,975 to Chiles et al. disclose metal coated synthetic rubber hoses used for circulation of fluids in radiant heating systems in houses and in businesses and disclose the use of an inner nylon tubular layer having a metal layer surrounding the nylon layer.

Polymeric material used to form the hose for accommodating fluids and gases under elevated pressures and/or high temperatures such as in automotive air conditioner cooler hoses and power steering hoses must meet other critical requirements. For example, the polymeric material must exhibit low permeability to FREON or other coolant gases to prevent such gases from escaping from the hose. Also such polymeric hose must be able to prevent outside moisture from entering the interior of the hose where it could contaminate the fluid or gas. In addition, the polymeric hose must be capable of withstanding high heat and pressure, be able to withstand engine and impact vibration, and be capable of forming gas-tight connections.

In the case of composite hoses for accommodating coolant fluid for automotive air conditioners, etc., polymeric materials such as polychloroprene (CR), acrylonitrile-butadiene rubber (NBR), chlorosulfonated polyethylene (CSM), chlorinated polyethylene (CPE), polyacrylate (PA), ethylene-acrylic rubber (AEM), alkyl acrylate copolymer (ACM), polyvinyl acetate, acrylonitrile-butadiene rubber (NBR), hydrogenated acrylonitrile-butadiene rubber (HNBR), ethylene-propylene-diene terpolymer (EPDM), cis-polybutadiene, cis-polyisoprene, polyurethane, polyamides such as nylon are often used as the material for forming the hose. For example, nylon 6 and nylon 66 are very low in coolant gas permeability, but are relatively high in moisture permeability. On the other hand, nylon 11 and 12 are relatively low in moisture permeability and less susceptible to hydrolysis, but are moderately high in gas permeability. Blends of any of the various nylons with other nylons, olefins or other materials are also used in such applications. For example, blends such as nylon 6, nylon 4, nylon 66, nylon 11, nylon 12, have been made to take advantage of desirable characteristics of one or more of such nylons and, at the same time, reduce the effects of any undesirable characteristics.

Ethylene-vinyl acetate copolymer (EVM) compositions are well known. For example, U.S. Pat. Nos. 6,492,454; 5,942,580; 5,837,791; 5,830,941; 5,807,948; 5,744,566; 5,698,651; 5,362,533; 5,135,988; 4,338,227 and 4,309,332 describes various ethylene-vinyl acetate copolymers and the uses thereof. Copolymers of ethylene and vinyl acetate exhibit elastomeric characteristics and are commonly used to improve adhesion properties of hot melt, solvent-based and pressure-sensitive adhesives. It is generally well known that the use of ethylene-vinyl acetate copolymers in the automotive industry and commercial applications are mostly limited to coatings, adhesives, gaskets, O-rings and the like. For example, "Ultrathene", a series of ethylene-vinyl acetate copolymers manufactured by Quantum Chemical, is typically used for adhesives, conversion coatings and thermoplastic modifiers. Such EVA copolymers exhibit a wide range of melt indexes. Ethylene-vinyl acetate copolymers are also marketed by Bayer under the trade name "Levapren". These EVA copolymers are described as oil and heat resistant materials which may be used in air hose applications. U.S. Pat. No. 6,605,327 to Ramey et al. teaches the use of two separate layers of an ethylene-vinyl copolymer in the manufacture of a multilayer hose. However, there is no mention of a copolymer containing a first vinyl ester and a second vinyl ester in which the first and second vinyl ester are different from each other.

Polymeric materials, such as ethylene-vinyl acetate copolymers and blends thereof have been employed in the wire and cable industry as a sheath or cover material surrounding electrical wires. For example, polymeric blends of ethylene-vinyl acetate copolymers with ethylene-vinyl acetate-carbon monoxide terpolymers which are particularly useful in applications where flame retardant, low smoke, oil resistant, flexible systems are desirable as a wire coating. For example, blends of ethylene-vinyl acetate copolymers with ethylene-vinyl acetate-carbon monoxide terpolymers are described in U.S. Pat. No. 6,133,367 to Arhart for use in automotive wire and cable coating applications. Other patents disclosing the use of ethylene-vinyl acetate copolymers as wire and cable coatings include 4,349,605 to Biggs et al.; 4,381,326 to Biggs et al.; 4,477,523 to Biggs et al.; 5,191,004 to Maringer et al.; 5,225,460 to Maringer et al.; and 5,226,489 to Maringer et al. None of the references describe a self supporting tubular structure, nor is there any teaching of a copolymer containing a first vinyl ester and a second vinyl ester wherein the two vinyl esters are different.

Choosing the right material or combination of materials to be used in the construction of automotive hoses is becoming more and more difficult because the hoses are now required to withstand higher pressures and temperatures than previous hoses performing the same tasks.

Also mandated regulations require that the hoses exhibit greater impermeability rates and resist stress over longer periods of time while maintaining manufacturing costs at an acceptable level. Therefore, the manufacturer of automotive hoses finds it necessary to come up with newer and better materials and combinations of materials to meet these rising needs.

SUMMARY OF THE INVENTION

It has now been discovered that certain copolymers containing two or more vinyl esters in which the two or more vinyl esters are different from each other, exhibit high temperature and pressure resistance, improved hydrocarbon fluid resistance and high damping characteristics. Such copolymers have been found to have promise as a material for use in the manufacture of a variety of industrial rubber goods such as automotive hoses, transmission belts, seals, dampers, engine mounts, etc. In particular, copolymers of a first vinyl ester and a second different vinyl ester are found to be particularly effective in forming hoses useful in the transmission of various automotive fluids and gases, e.g., engine oil cooler fluids, transmission oil cooler fluids, power steering fluids, radiator fluids, heater fluids, and the like. For example, copolymers containing a first vinyl ester of a C₂ to C₆ carboxylic acid, e.g., vinyl acetate, and a second vinyl ester which is different from the first vinyl ester such as vinyl palmitate, vinyl stearate, vinyl laurate, etc. exhibit high temperature resistance, hydrocarbon fluid resistance and high damping characteristics. Typically, the second vinyl ester is a higher vinyl ester having a higher number of carbons, e.g., C₁₀ or higher. Such vinyl esters have promise as a material for use in the manufacture of elastomeric automotive components such as hoses, belts, seals, dampers, engine mounts, etc. In particular, the vinyl ester copolymers are useful in the manufacture of hoses for transporting various automotive fluids and gases, e.g., engine oil cooler fluids, transmission oil cooler fluids, power steering fluids, radiator fluids, heater fluids, and the like. Preferably, the copolymer is a vinyl acetate-vinyl laurate copolymer.

In one embodiment of the invention, the polymeric component of the polymeric composition is a vinyl ester copolymer containing a first vinyl ester and a second vinyl ester wherein the first vinyl ester is a vinyl ester of a lower carboxylic acid or acyl halide having about six or less carbons and the second vinyl ester is a higher vinyl ester containing about ten or more carbons. Typically, the polymeric composition is a copolymer wherein the first vinyl ester is a C₂ - C₆ aliphatic carboxylic acid and the second vinyl ester is a higher vinyl ester containing at

least 10 carbons. Preferably, the first vinyl ester is vinyl acetate and the second vinyl ester is vinyl laurate.

In another embodiment of the invention, the vinyl ester copolymer containing the first vinyl ester and the second vinyl ester is blended with another polymeric component such as ethylene-vinyl esters of a lower carboxylic acid, e.g., ethylene-vinyl acetate copolymers, chlorinated polyolefins, chlorosulfonated polyolefins, polychloroprene (CR), ethylene-acrylic rubber (AEM), alkyl acrylate copolymer (ACM), polyvinyl acetate, ethylene-propylene-diene monomer (EPDM), styrene-butadiene rubber (SBR), acrylonitrile-butadiene rubber (NBR), hydrogenated acrylonitrile-butadiene rubber (HNBR), ethylene-propylene rubber (EPR), ethylene-propylene-hexadiene terpolymer, butyl rubber, cis-polybutadiene, cis-polyisoprene, polyurethane, polyamide, and the like, and mixtures thereof.

Other ingredients or additives which serve to provide or enhance the required heat tolerance, pressure resistance, fluid permeation resistance, etc., may be included as additional components of the polymeric composition of the present invention. Such ingredients or additives include: process aids, fillers, plasticizers, metal oxides and/or hydroxides, peroxides, coagents, antioxidants, and other ingredients which are customarily added to polymeric materials to provide a desired purpose.

In one aspect of the invention, there is provided a heat tolerant, pressure resistant elastomeric composition containing a copolymer of a first vinyl ester and a second vinyl ester which is different from the first vinyl ester, wherein the composition exhibits improved hydrocarbon fluid impermeability when compared to ethylene-vinyl acetate copolymers. The composition is useful in the manufacture of various automotive components such as hoses, belts, seals, dampers, engine mounts, etc.

In another aspect of the invention, there is provided a heat tolerant, pressure resistant elastomeric hose which comprises a first vinyl ester of a C_2 to C_6 carboxylic acid or acyl halide copolymerized with a second vinyl ester which is different from the first vinyl ester such as a fatty ester. The hose is particularly useful in the automotive industry to transport fluids and gases at high temperatures and pressures. For example, the hose of the invention is particularly useful in the transportation of air conditioner fluids, power steering fluids, transmission oil cooler fluids, etc. where the material forming the hose exhibits the required heat tolerance, pressure resistance, impermeability resistance to the fluid being transported through the hose etc.

In still another aspect of the invention, there is provided a method for producing the hose of the present invention which comprises a first vinyl ester of a lower carboxylic acid or acyl halide copolymerized with a second vinyl ester which is a different vinyl ester.

The term "fluid" as used herein to define the substance transported through the tubular structure is intended to include gases as well as liquids.

DETAILED DESCRIPTION OF THE INVENTION

In accordance with a first embodiment of the invention, a polymeric composition comprising a copolymer of a first vinyl ester of a C₂ - C₆ lower aliphatic carboxylic with a second vinyl ester which is a different vinyl ester is described. Typically, the first vinyl ester is vinyl acetate, and the second vinyl ester is vinyl laurate.

Vinyl ester copolymers containing vinyl acetate and vinyl laurate are commercially available under the trade names Vinnapas B500/20 VL and Vinnapas 500/40 VL from Wacker-Chemie GmbH. In accordance with the invention, the vinyl ester copolymers containing a first vinyl ester and a second vinyl ester are compounded with a plurality of additives such as certain process aids, fillers, plasticizers, metal oxides and/or hydroxides, peroxides, coagents, antioxidants, etc. to enhance the heat tolerance, pressure resistance and/or hydrocarbon fluid impermeability of the vinyl ester compositions of the present invention.

While the vinyl acetate-vinyl laurate copolymer is typically the sole polymeric component and the primary ingredient of the composition, the vinyl acetate-vinyl laurate copolymers of the invention may also be combined with other elastomeric polymers to provide certain desirable properties to the vinyl acetate-vinyl laurate copolymers. Typically, such other elastomeric polymers include ethylene-vinyl ester copolymers in which the vinyl ester component is an ester of a C₂ to C₆ carboxylic acid. Preferably, the ethylene-vinyl ester copolymer is an ethylene-vinyl acetate copolymer. Other elastomeric polymers include chlorinated polyolefins, chlorosulfonated polyolefins, polychloroprene (CR), ethylene-acrylic rubber (AEM), alkyl acrylate copolymer (ACM), polyvinyl acetate, ethylene-propylene-diene monomer (EPDM), styrene-butadiene rubber (SBR), acrylonitrile-butadiene rubber (NBR), hydrogenated acrylonitrile-butadiene rubber (HNBR), ethylene-propylene rubber (EPR), ethylene-propylene-hexadiene terpolymer, butyl rubber, cis-polybutadiene, cis-polyisoprene, polyurethane, polyamide, and the like, and mixtures thereof. Such elastomeric polymers are well

known and are readily available in the rubber industry. For example, ethylene-vinyl acetate copolymers are commercially available from a number of manufacturers including DuPont, Millennium Petrochemicals, Nova-Borealis Compounds LLC, AT Plastics Inc., Exxon, ATO Chem., Bayer AG, and others. Suitable ethylene-vinyl acetate copolymers have a vinyl acetate content greater than about 40%, preferably greater than about 50% and most preferably about 60 to 90% vinyl acetate. Ethylene-vinyl acetate copolymers available from Bayer AG under the name Levapren have been found to be particularly useful in the present invention.

Additional materials may also be employed as additives compounded into the copolymer composition for the purpose of providing desired characteristics of the composition. These additional materials include, for example, process aids in an amount up to about 8%; fillers in an amount of about 20 to 60%; plasticizers in an amount up to about 15%, preferably about 3 to 15%; metal oxides or hydroxides in an amount up to about 8%; peroxides in an amount up to about 5%; coagents in an amount up to about 5%; and antioxidants in an amount up to about 5%. Other additives such as vulcanization accelerators commonly used in polymeric compositions for use in preparing hoses may be added in appropriate amounts to provide their desired effect.

Suitable processing aids include stearic acid, stearates, polyethylene, amines, oils, organic esters, organic phosphate esters and the like.

Suitable fillers include materials, such as carbon black, silicon dioxide, fumed silica, precipitated silica, diatomaceous earth, magnesium carbonate, magnesium silicate, aluminum silicate titanium dioxide, talc, mica, aluminum sulfate, calcium sulfate, graphite, wollastonite, molybdenum disulfide, clay, calcium carbonate and combinations thereof.

Suitable plasticizers include materials such as hydrocarbons, glycols, aldehydes, ethers, esters, ether-esters, and the like.

Suitable metal oxides and metal hydroxides include zinc oxide, zinc hydroxide, magnesium oxide, magnesium hydroxide, calcium oxide, calcium hydroxide, aluminum hydroxide, and the like.

Suitable peroxides include 2,5-dimethyl-2,5-di(t-butylperoxy)hexyne-3; 2,5-dimethyl-2,5-di(t-butylperoxy)hexane; α,α' -bis-(t-butylperoxy)-p-diisopropylbenzene, dicumyl peroxide, di-t-butyl peroxide; 1,1-bis(t-butylperoxy)-3,3,3-trimethylcyclohexane; 2,4-dichlorobenzoyl peroxide; benzoyl peroxide; p-chlorobenzoyl peroxide; 4,4-bis(t-butylperoxy) valerate; t-butylcumyl peroxide; di-t-amyl peroxide; t-butyl hydroperoxide and combinations thereof.

Suitable coagents include N, N',m-Phenylenedimaleimide (HVA2) and other bismaleimides; triallyl cyanurate; triallyl isocyanurate; diallyl terephthalate; 1,2-vinyl polybutadienes; di- and tri-functional methacrylates and diacrylates; and metal ion versions of these coagents.

Suitable antioxidants include phenols, hydrocinnamates, diphenylamines, hydroquinone, hydroquinolines, mercaptobenzimidazoles, and the like.

In accordance with a first embodiment of the invention, the vinyl acetate-vinyl laurate copolymer composition comprises:

about 2 to 75% vinyl acetate-vinyl laurate copolymer;

about 0 to 75% by weight ethylene-vinyl acetate;

about 0.8 to 2% process aid selected from the group consisting of stearic acid, stearates, polyethylene, amines, oils, organic esters, organic phosphate esters and combinations thereof;

about 20 to 60% filler selected from the group consisting of carbon black, silicon dioxide, fumed silica, precipitated silica, diatomaceous earth, magnesium carbonate, magnesium silicate, aluminum silicate titanium dioxide, talc, mica, aluminum sulfate, calcium sulfate, graphite, wollastonite, molybdenum disulfide, clay, calcium carbonate and combinations thereof;

about 3 to 15% plasticizer selected from the group consisting of hydrocarbons, glycols, aldehydes, ethers, esters, ether-esters and combinations thereof;

about 0 to 10% metal oxides and/or hydroxides selected from the group consisting of zinc oxide, zinc hydroxide, magnesium oxide, magnesium hydroxide, calcium oxide, calcium hydroxide, aluminum hydroxide and combinations thereof;

about 0.5 to 2% peroxide selected from the group consisting of 2,5-dimethyl-2,5-di(t-butylperoxy)hexyne-3; 2,5-dimethyl-2,5-di(t-butylperoxy)hexane; dicumyl peroxide; α,α' -bis-(t-butylperoxy)-p-diisopropylbenzene; di-t-butyl peroxide; 1,1-bis(t-butylperoxy)-3,3,3-trimethylcyclohexane; 2,4-dichlorobenzoyl peroxide; benzoyl peroxide; p-chlorobenzoyl peroxide; 4,4-bis(t-butylperoxy) valerate; and combinations thereof;

about 0 to 5% coagent selected from the group consisting of maleimides, triallyl cyanurate, triallyl isocyanurate, diallyl terephthalate, 1,2-vinyl polybutadiene, di- and tri-functional methacrylates, diacrylates, metal ion versions thereof and combinations thereof; and

about 0 to 0.3% antioxidant selected from the group consisting of phenols, hydrocinnamates, hydroquinones, hydroquinolines, diphenylamines, mercaptobenzimidazoles, and combinations thereof.

In accordance with a first preferred embodiment of the invention, the composition comprises:

about 2 to 75% by weight vinyl acetate-vinyl laurate copolymer containing about 50 to 80% vinyl acetate and about 50 to 20% vinyl laurate;

about 0.2 to 0.7% by weight stearic acid;

about 23 to 38% by weight carbon black;

about 2 to 5% by weight silicon dioxide;

about 3 to 7% by weight trioctyl trimellitate;

about 0 to 7% by weight adipate type plasticizer;

about 0 to 8% by weight magnesium oxide;

about 0.1 to 0.75% 1-octanedecanamine;

about 0.1 to 0.75% organic phosphate ester;

about 0.5 to 4% by weight organic peroxide;

about 0.25 to 1% by weight triallyl cyanurate;

about 0.25 to 1% by weight N,N', n-phenylenedimaleimide;

about 0.25 to 2% by weight antioxidant selected from the group consisting of phenols, hydrocinnamates, diphenylamines, hydroquinones, hydroquinolines and mixtures thereof.

In accordance with a second preferred embodiment of the invention, the composition comprises:

about 5 to 30% by weight vinyl acetate-vinyl laurate copolymer containing about 50 to 80% vinyl acetate and about 50 to 20% vinyl laurate;

about 20 to 50% by weight ethylene-vinyl acetate copolymer containing about 50 to 80% vinyl acetate and about 80 to 50% ethylene;

about 0.2 to 0.7% by weight stearic acid;

about 23 to 38% by weight carbon black;

about 2 to 5% by weight silicon dioxide;

about 3 to 7% by weight trioctyl trimellitate;

about 0 to 7% by weight adipate type plasticizer;

about 0 to 8% by weight magnesium oxide;

about 0.1 to 0.75% 1-octanedecanamine;

about 0.1 to 0.75% organic phosphate ester;

about 0.5 to 4% by weight organic peroxide;

about 0.25 to 1% by weight triallyl cyanurate;

about 0.25 to 1% by weight N,N', n-phenylenedimaleimide;

about 0.25 to 2% by weight antioxidant selected from the group consisting of phenols, hydrocinnamates, diphenylamines, hydroquinones, hydroquinolines and mixtures thereof.

In a second aspect of the invention, a tubular structure formed from the aforementioned vinyl acetate-vinyl laurate compositions is described. The tubular structure is useful for conveying automotive fluids in, for example, engine oil cooler, transmission oil cooler, power transmission cooler, radiator, heater, etc.

In a third embodiment of the invention, a method for manufacturing heat tolerant, pressure resistant hoses having improved hydrocarbon fluid resistance is provided. The method includes providing a copolymer of a first vinyl ester and a second vinyl ester; mixing the first vinyl ester-second vinyl ester copolymer with various additives and, optionally with other elastomeric polymers via open mill mixing or internal mixer such as a Banbury mixer; and forming a heat tolerant, pressure resistant hose having improved hydrocarbon fluid impermeability.

In a preferred method for manufacturing the tubular structure of the invention, a continuous spiral production method is employed which comprises:

providing an inner layer of a material produced in a mono-extrusion of an annular configuration;

applying a reinforcement material to the annular extrudate in a two-layer spiral format in which one layer is applied in a clockwise direction and the other layer is applied in a counter-clockwise direction.

applying an outer layer over the reinforcement layer in a mono-extrusion of an annular configuration;

vulcanizing the composite tubular structure in an autoclave.

A reinforcing material is generally employed in the manufacture of the hose to provide strength to the hose structure. The reinforcement materials include natural fibers such as cotton; synthetic fibers such as polyester, nylon, rayon, aramid; and metal wire. The reinforcement may be applied by knit or maypole type braid methods. Typically, the reinforcement material is applied to the annular extrudate in a two-layer spiral format in which one layer is applied in a clockwise direction and the other layer is applied in a counter-clockwise direction.

An outer protective cover layer may be employed over the reinforcing layer in a mono-extrusion of an annular configuration to provide protection for the hose from the outer environment. The cover is a protective layer of any of the commercially recognized materials for such use, e.g., elastomers, thermoplastic polymers, thermosetting polymers and the like. Typically, the protective cover is a synthetic elastomeric having good heat resistance, oil resistance, weather resistance and flame resistance. Preferably, the outer protective cover layer is a synthetic elastomer selected from the group consisting of styrene-butadiene rubber; butadiene-nitrile rubber such as butadiene-acrylonitrile rubber; chlorinated rubber; chlorosulfonated polyethylene; chlorinated polyethylene; vinylethylene-acrylic rubber; acrylic rubber; epichlorohydrin rubber such as Hydrion 200, a copolymer of epichlorohydrin and ethylene oxide available from DuPont ECO; polychloroprene rubber; polyvinyl chloride; ethylene-propylene copolymers; ethylene-propylene-diene terpolymer; ultra high molecular weight polyethylene; high density polyethylene; and blends thereof.

EXAMPLES

Parts per hundred of polymer (phr)

Levapren® 600 HV	100	75	75				
Vinnapas® B 500/20 VL		25			50	50	
Vinnapas® B 500/40 VL			25	100	50	50	100
Stearic Acid	1	1	1	1	1	1	1
Magnesium Oxide	10	10	10	10	10	10	10
N650 Carbon Black	70	70	70	70	70	70	70
Silicon Dioxide	5	5	5	5	5	5	5
Trioctyl Trimellitate	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Adipate Plasticizer	2.5	2.5	2.5	2.5	2.5	2.5	2.5
1-Octadecanamine	1	1	1	1	1	1	1
Poly(oxy-1,2-ethanediyl),alpha-octadecyl- omega-hydroxy,-phosphate	1	1	1	1	1	1	1
Triallyl Cyanurate, 72% Dispersion	1	1	1	1	1	1	1
N,N' -m-Phenylene Dimaleimide	1	1	1	1	3	1	1
Dicumyl Peroxide; 99%	2.4	2.4	2.4	2.4	2.4	2.4	2.4
95% a,a',bis t,butylperoxy diisopropylbenzene						1	1
4,4'-Di(methylbenzyl)diphenylamine	2	2	2	2	2	2	2

Cured 20 minutes @ 175 °C

Original Properties

Tensile Strength; psi	1990	1598	1661	1001	1054	1263	1186
Elongation%	262	240	265	184	164	139	134
100% Modulus; psi	841	748	615	121	837	1033	947
Hardness; Shore A	74	79	76	78	82	85	78
Compression Set, 70h. @ 175 °C	49	52	52	61	65	59	59

After 168 hours @ 175 °C in Air

Tensile Strength; psi	1796	1617	1356	1152	1668	1692	1293
Elongation%	262	182	194	103	51	47	66
100% Modulus; psi	1129	1429	1199	1075	n/a	n/a	n/a
Hardness; Shore A	84	92	90	83	96	82	87

After 70 hours @ 175 °C in Chrysler MS9602 Automatic Transmission Fluid

Tensile Strength; psi	1624	1559	1341	1063	998	1118	947
Elongation%	265	240	272	119	122	122	149
100% Modulus; psi	518	581	406	900	973	1055	628
Hardness; Shore A	56	74	54	81	89	88	66
Volume Change; %	28	21	26	19	9	9	17

After 70 hours @ 175 °C in IRM 903 Oil

Tensile Strength; psi	1225	1156	954	392	834	851	557
Elongation%	202	205	186	123	138	107	107
100% Modulus; psi	490	484	409	306	614	534	489
Hardness; Shore A	39	55	35	37	80	75	48
Volume Change; %	79	63	76	59	32	31	52

Levapren is a trademark of Bayer Corporation

Vinnapas is a trademark of Wacker-Chemie GmbH

While preferred embodiments of the invention have been described in detail and exemplified in the above examples and specification, it will be apparent to those skilled in the art that the invention may be modified without deviating from the scope of the invention. Therefore, the foregoing examples and description are to be considered exemplary rather than limiting and are not to be limited thereto.

What is claimed is: